Computer Exercises to Incorporate Energy Concepts into the Electrical Engineering Curriculum

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Abstract

The authors report on a sponsored project to incorporate power concepts into non-power courses. Reported here are efforts to build computer exercises to accomplish a portion of this task.

1. Introduction

In 1997 the National Science Foundation funded university programs to enhance electric power education in the United States in light of a perceived shortage of competent engineers with a power engineering background. A variety of approaches to this enhancement are being explored at eight institutions funded by the project. The University of Wyoming was fortunate to be able to participate in this effort and many of these curricular changes have been reported elsewhere.[1] What will be outlined here are some of the computer exercises integrated into the non-power portions of the EE curriculum that address power issues.

The University of Wyoming has a modest program in electrical power so a significant part of our effort was devoted to the incorporation of electrical power concepts into non-power courses such as electronics, signals and systems, digital design and microprocessor system design. The three courses discussed here are the required sophomore linear systems course, the required junior electric networks course, and a senior elective digital signal processing course.

2. Linear Systems

The topics in the linear systems course are Laplace transforms, electrical and mechanical system modeling, transfer functions, poles and zeros, frequency response, convolution, Fourier series, and filtering of periodic signals. When Fourier analysis is discussed a laboratory exercise has been developed that addresses the topic of power quality, particularly harmonics present on the electric power grid and how they might be eliminated to protect appliances, computers and communication equipment. Of course this can be accomplished by lowpass filtering of the line voltage but if current is a consideration this is not a practicable strategy. Power engineers have found a more constructive solution which amounts highpass filtering the harmonics, reversing their phase and recombining these with the original signal to cancel the higher harmonics originally present. This phase reversal and cancellation is accomplished by the use of transformers.

The exercise used in our laboratory is a much simplified version of this scenario wherein current is not considered. The original distorted line signal is given to the students as a data file. They are to perform a Fourier analysis in MATLAB to establish the harmonic content. They are asked to find both the amplitude and phase spectra and to convert the phase spectrum to temporal delay to be used in the waveform synthesis using sinusoidal signal sources in VisSim. The synthesis of the waveform is illustrated at the left side of Fig. 1 where the harmonic suppression scheme is illustrated in the right side of Fig. 1.

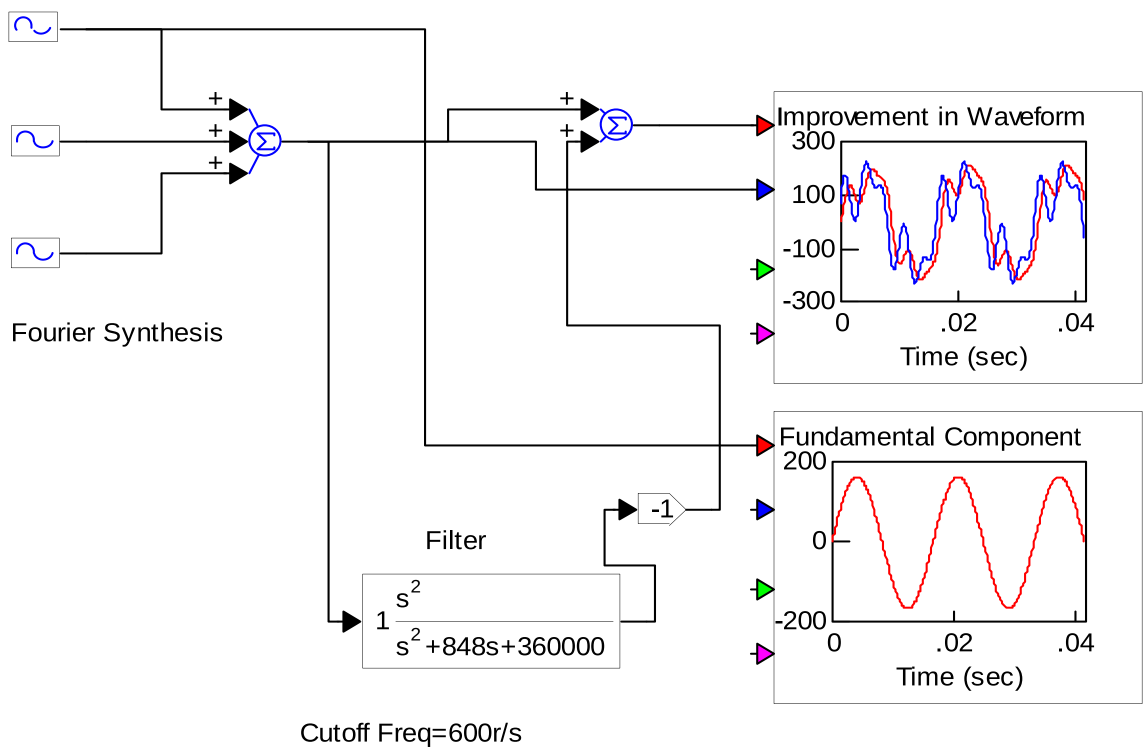

Figure 1. VisSim Diagram for Waveform Synthesis and Harmonic Distortion Suppression.

Students can easily investigate the effect of filter order and the tradeoff between filter cutoff frequency and the harmonic distortion of the resulting signal.

3. Electric Networks

The electric networks course follows the first circuit analysis course and the linear systems course. The topics for this course are complex power, Fourier transforms, mutual inductance, coupled circuits, transformers, three-phase circuits, resonance, and two-port networks. The course makes extensive use of Spice for circuit analysis and simulation. Two of those exercises are outlined below.

The first exercise in this course uses a combination of Spice simulation and laboratory experiment to investigate power factor correction in a circuit with a source and an inductive load.

The use of Spice makes the phasor calculations easy since steady-state answers are presented in magnitude and phase form. Also by dealing with time domain data makes correlation with the benchtop lab data an easy task. The circuit considered by the students is shown in Fig. 2.

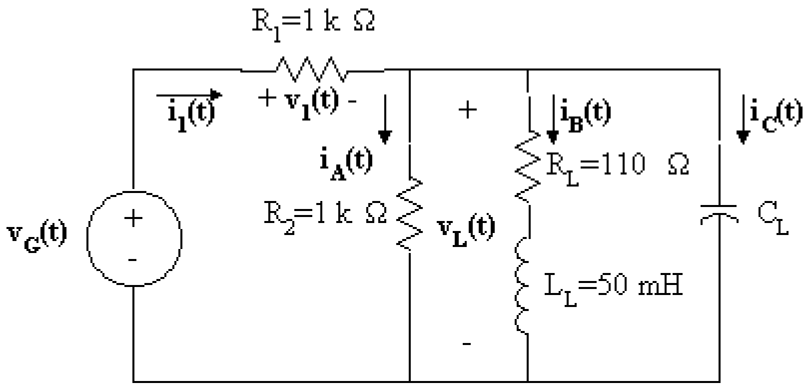

Figure 2. Power Factor Correction Circuit Problem.

Students are asked to find the optimal capacitor which will make phase shift between source current $i_1(t)$ and the load voltage $v_L(t)$ zero. They are then asked to double this capacitance and find the frequency at which the correction is now accomplished. Students gain knowledge that the idea of power factor correction is a single frequency concept.

The second power related computer exercise involves the Spice simulation of a three-phase delta connected circuit shown in Fig. 3. Students are asked to find the equivalent wye circuit and to simulate a single-phase of that circuit. This means that the wye impedances will be a third of the delta impedances and the wye voltage sources will be $1/\sqrt{3}$ times the magnitude of the delta voltage sources and the phases will be shifted by 30° in the appropriate direction.

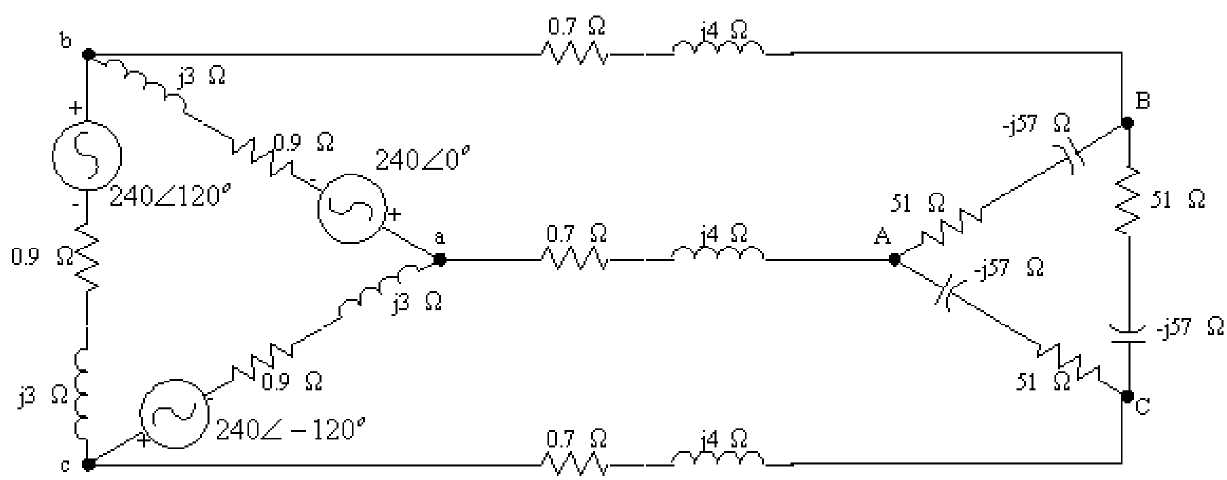

Figure 3. Delta Connected Three-Phase Network To Be Simulated In Spice.

The first power related exercise in the electric network course is that of power factor correction. The use of capacitors for power factor correction is explored with Spice as is a simulation of all three phases of a balanced three-phase network.

4. Digital Signal Processing

The prerequisite for the digital signal processing course is the junior level course in discrete signals and systems. The topics explored in the digital signal processing course include sampling, aliasing, A/D and D/A conversion, applications of the discrete Fourier transform, the FFT algorithm, computation of correlation functions and periodograms, and spectral estimation.

The first exercise that is power related is that of a signal that is badly contaminated with 60 Hz noise plus harmonics thereof. This typically occurs in instrumentation and communication signals. The signal considered here is a 50 Hz squarewave with the additive noise as illustrated in Fig. 4(a). Students are asked to compute a power spectrum for the signal as that of Fig. 4(b) in order to visualize the harmonic content of the signal. The logical way to improve the signal-to-noise ratio is to employ a comb filter to attenuate the noise at 60 Hz and multiples thereof.

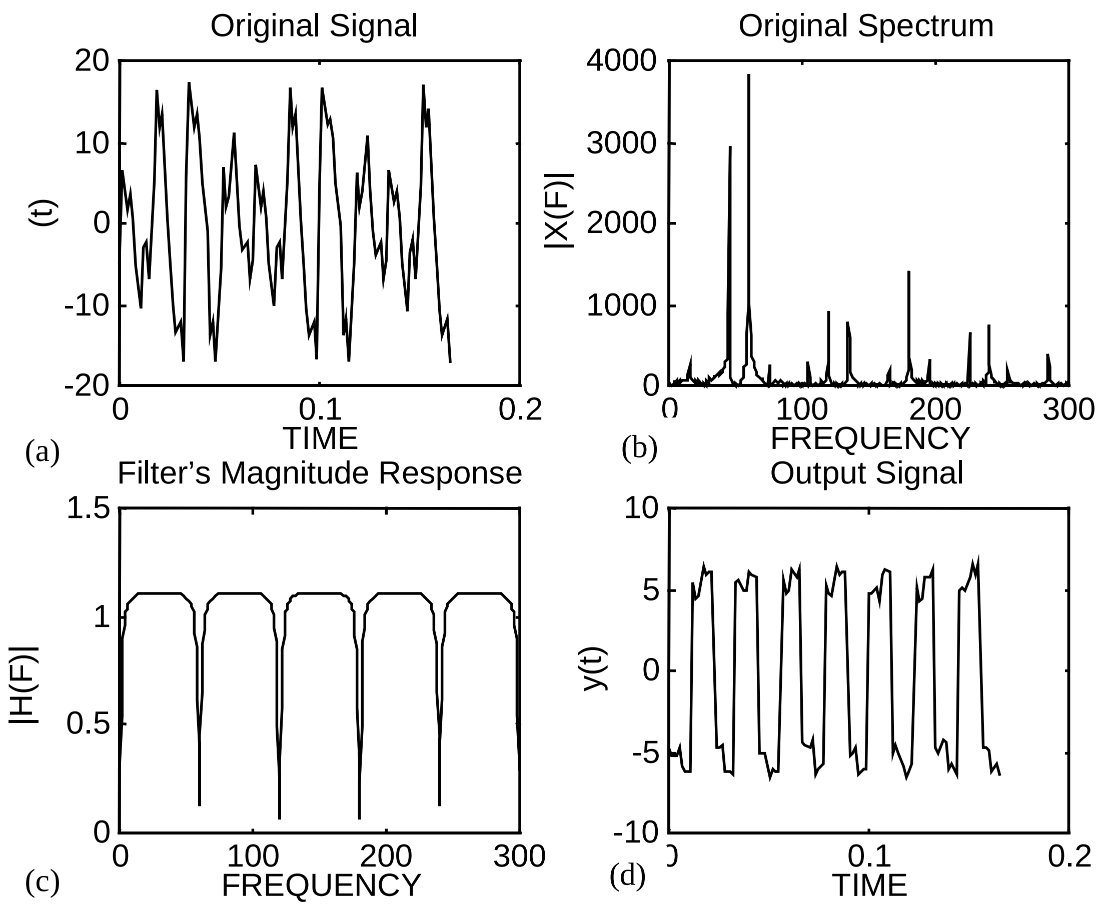

Figure 4. Comb Filtering of a 50 Hz Squarewave Contaminated by Noise at 60Hz and Harmonics Thereof.

The gain of this filter is illustrated in Fig. 4(c). The resulting comb filtered signal is illustrated in Fig. 4(d).

A second exercise employed in the signal processing course is one taken from the power industry. It is used to illustrate the utility of spectral estimation to estimate inter-area low frequency electromechanical modes of oscillation. These modes typically occur in the range of 0.2 to 0.6 Hz and there are some indications that changes in character of these oscillations may be the precursor to a power system voltage collapse. Accurate estimation of these modes is a critical part of analysis, control and operation of a power system.

Students are asked to first visually examine the temporal power to see if there are such signals present. While examining the recorded data of Fig. 5(a) it is difficult to see the low frequency content while examination of Fig. 5(b) indicates that there is definite low frequency content which is yet to be determined.

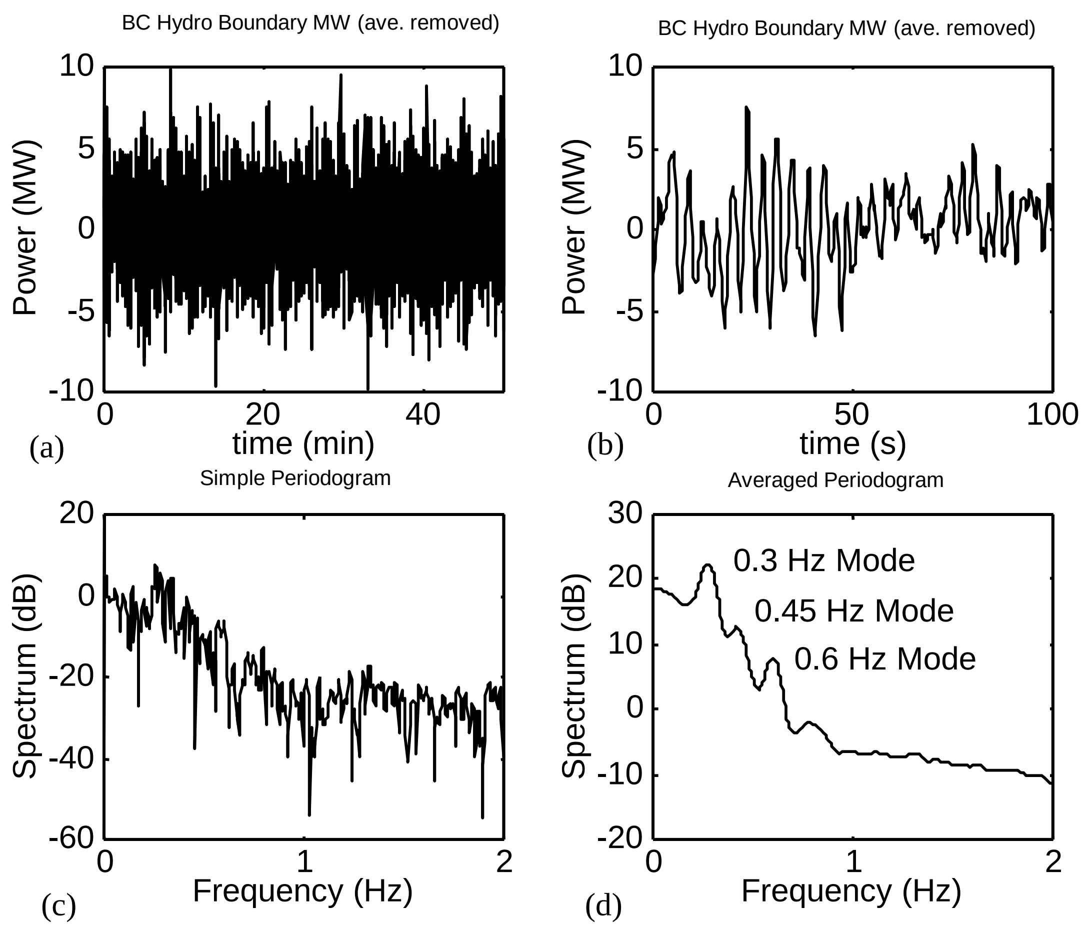

Figure 5. BC Hydro Temporal Power History and Periodograms Derived Therefrom.

The periodogram derived from a single block of the recorded data is shown in Fig. 5(c) where it still very difficult to see what frequencies are present. Students are then asked to compute a series of ten periodograms and average them. This yields the averaged periodogram illustrated in Fig. 5(d) where it is now easy to see the primary frequency content at 0.3Hz, 0.45 Hz and 0.6 Hz.

5. Conclusion

Students have reacted positively to these modifications to their computing exercises because these problems are all concerned with real problems such as they may encounter in engineering practice.

6. Acknowledgments

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Bibliography

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